Rotorcraft Survivability Advancements through Technology

By

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Presented at the

American Defense Preparedness Association {ADPA}
National Security Industrial Association {NSIA}

on

Enhancing Aircraft Survivability

A Vulnerability Perspective

Monterey, CA 23 October 1997

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Nikolaos (Nick) Caravasos

Mr. Caravasos has 36 plus years of aircraft experience with Boeing; 32 plus years in research & development and 4 years in commercial and rotorcraft designs.

Education/Training

University of Pennsylvania	MS in Applied Management
West Virginia University	BS in Engineering
UCLA, Widener, WVU	Graduate and Specialty Courses

Employment History

1984 to Present - Manager, Military Technology, Boeing Philadelphia
- Responsible for management of Military Technology IR&D program
- Technical & Management Support to Boeing's fixed wing & rotary wing products
- Manager of numerous Army. Navy, & JTCG/AS contracts

1965 to 1983 - Boeing Helicopters, Staff Specialist
- Responsible for Survivability on all Boeing Helicopter products
- Marketing support - Supported marketing activities worldwide.

1961 to 1965 - Boeing Helicopters and Boeing Commercial Airplane Senior Engineer
- Responsible for empennage and passenger accommodations designs

Publications/Awards

- Received the highest IR&D score at Boeing Helicopters in 1985, 1986, 1987, & 1988
- Annual lectures on "Aircraft Combat Survivability" and graduate "Helicopter Design" Courses at the Naval Post Graduate School, Monterey, California
- Lectured to Greece's NATO forces at KETA, Glyfada, Athens, Greece
- Presented and published numerous technical papers for ADPA, AIAA, AAAA, and AHS

Affiliations

- AIAA Survivability Committee - Chairman from 1992 to 1994
- Member of JTCG/AS Industry Advisory Committee

Outline

Nitrogen Inflated Ballistic Bladder {NIBB}

Features

- *Hydrodynamic Ram*
- *Crashworthiness*
- *Explosion/Fire Suppression*

Status

- *Phase I Cube Tests {MIL-T-27422}*
- *Video {Ballistic & 65-ft Crash Drop Tests}*

Conclusions

Thermoplastics Research

Tailboom Contract & IR&D Summary

- *Design, Analysis, Fabrication, & Tests*
- *IR&D Support*
- *Video*

Conclusions

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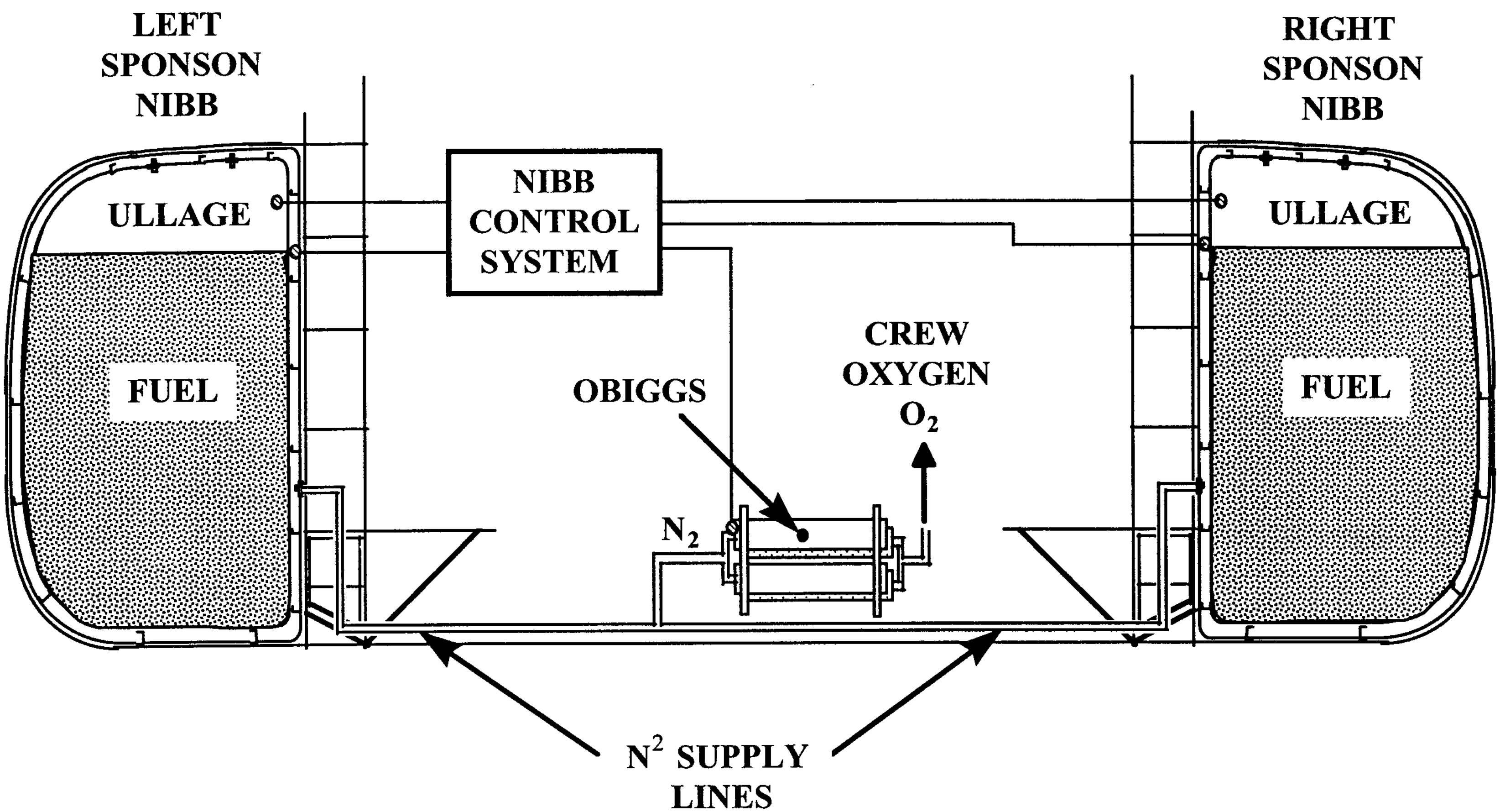
Typical Rotorcraft Fuel System Set-up



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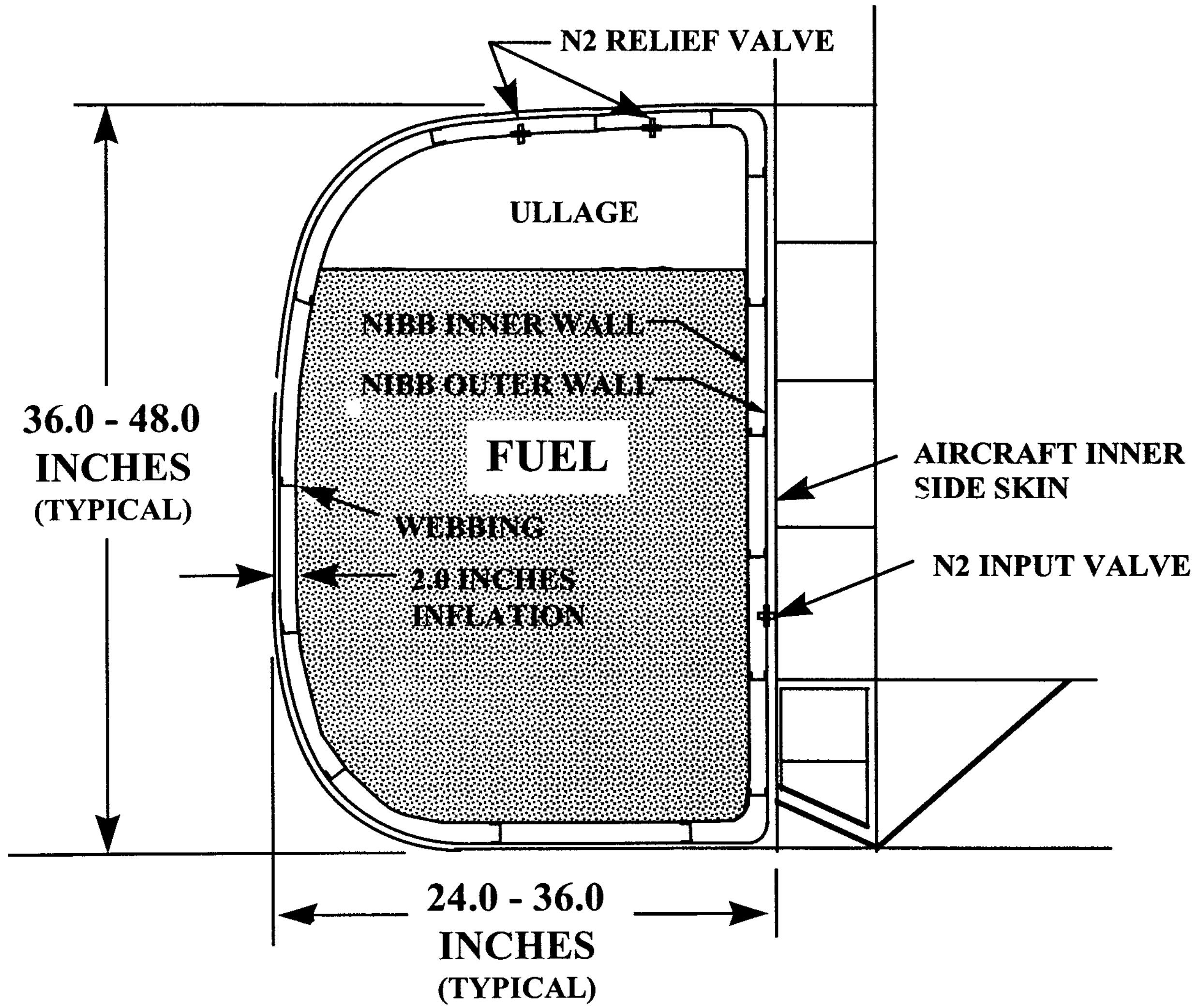
Typical Rotorcraft Fuel Cell



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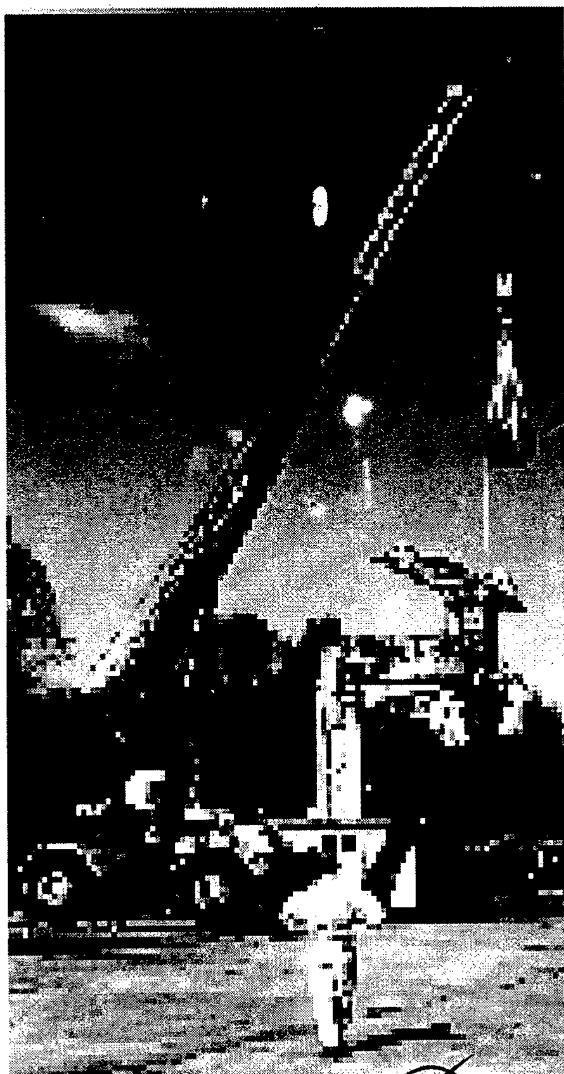
NIBB Cube Testing



Cube Raised to 65-ft Height for Drop Test

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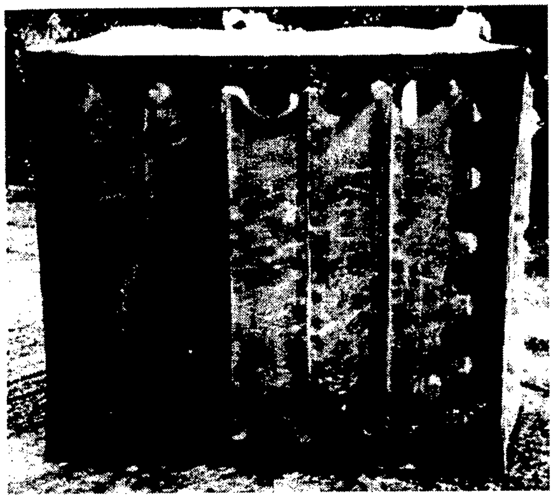
Drop Test Results

No damage to tank walls, seams, or corners

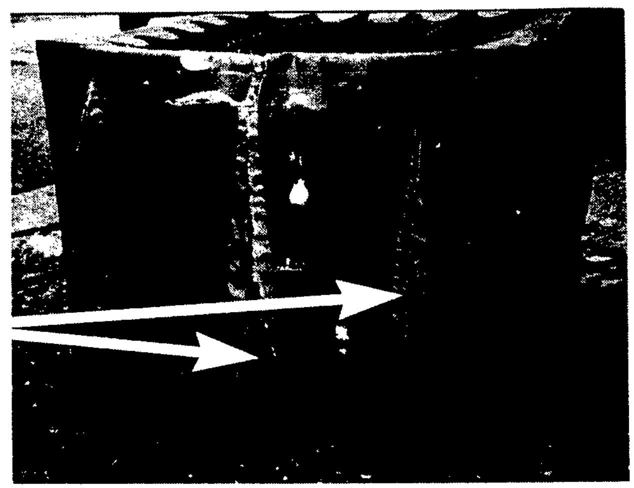


Bottom View

Results of visual inspection

Rubber plugs inside tank detached from tubes allowing water leakage 4 to 5 seconds after impact

Side View



Damage to NIBB outer wall
(This is expected since it is not part of the crashworthiness design)

No leakage during post test air inflation test [0.5 psi]

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Nitrogen Inflated Ballistic Bladder

Conclusions

Where are we?

- *Qualified Concept to Phase I MIL-T-27422 Cube*
  - *Met Drop Test from 65-ft Height*
  - *No damage to surrounding structure from hydrodynamic ram*
  - *Provided self-sealing against 12.7mm tumbled API*

Where do we from here?

- *Phase II Full Scale Qualification*

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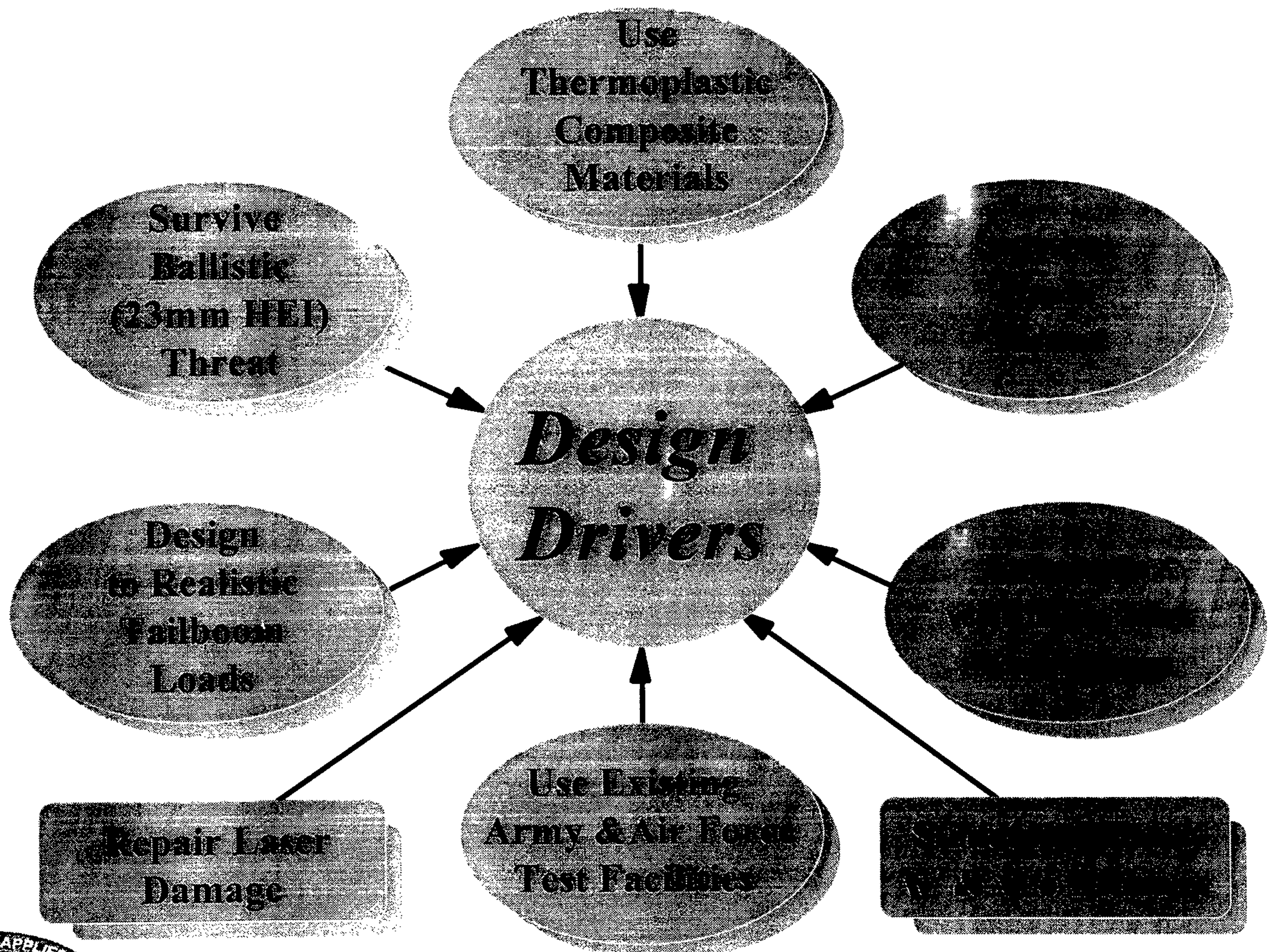
R&D Thermoplastic Tailboom Program

Program Design Drivers



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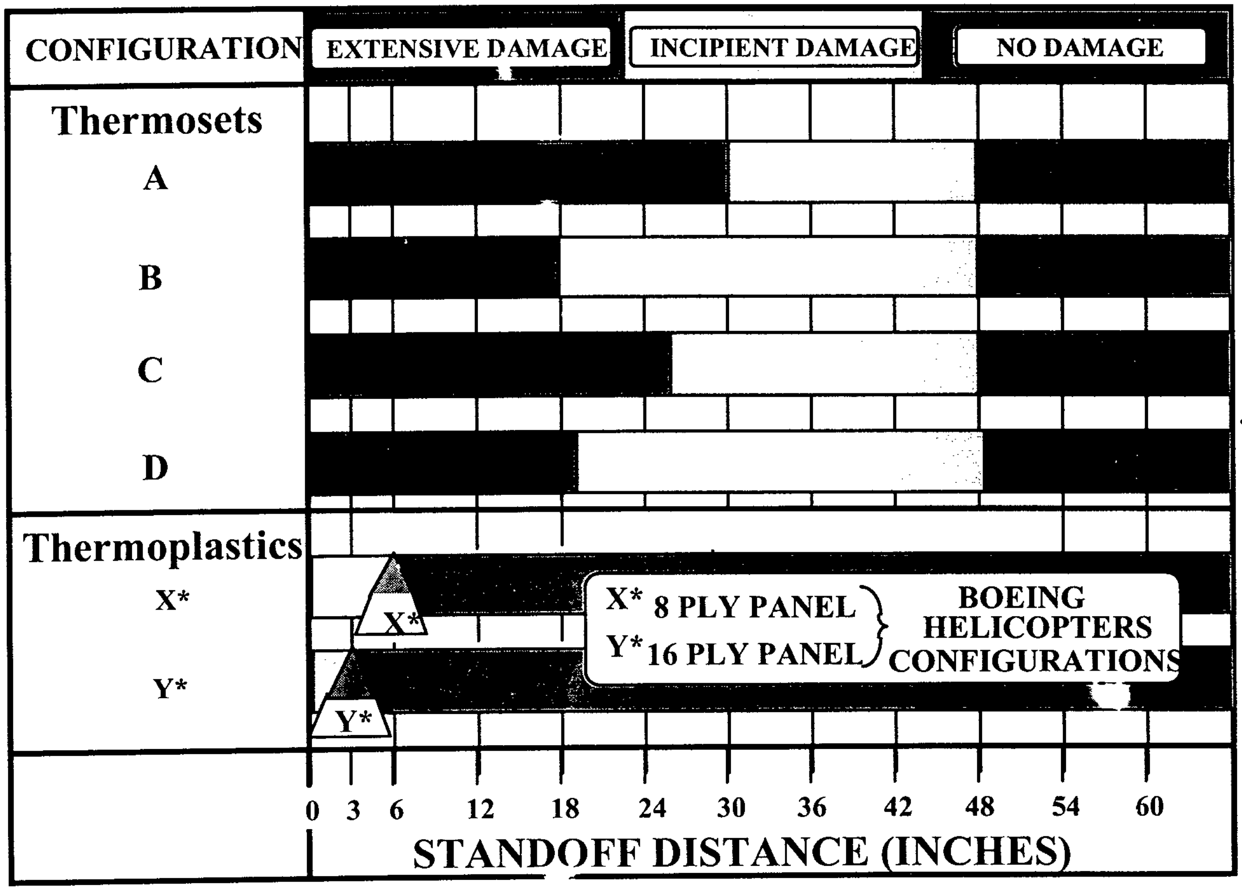
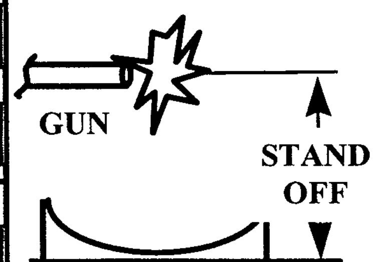
Thermoplastic Panels Survive Blast Pressures

IR&D Program

COMPARISON OF 20mm TEST RESULTS





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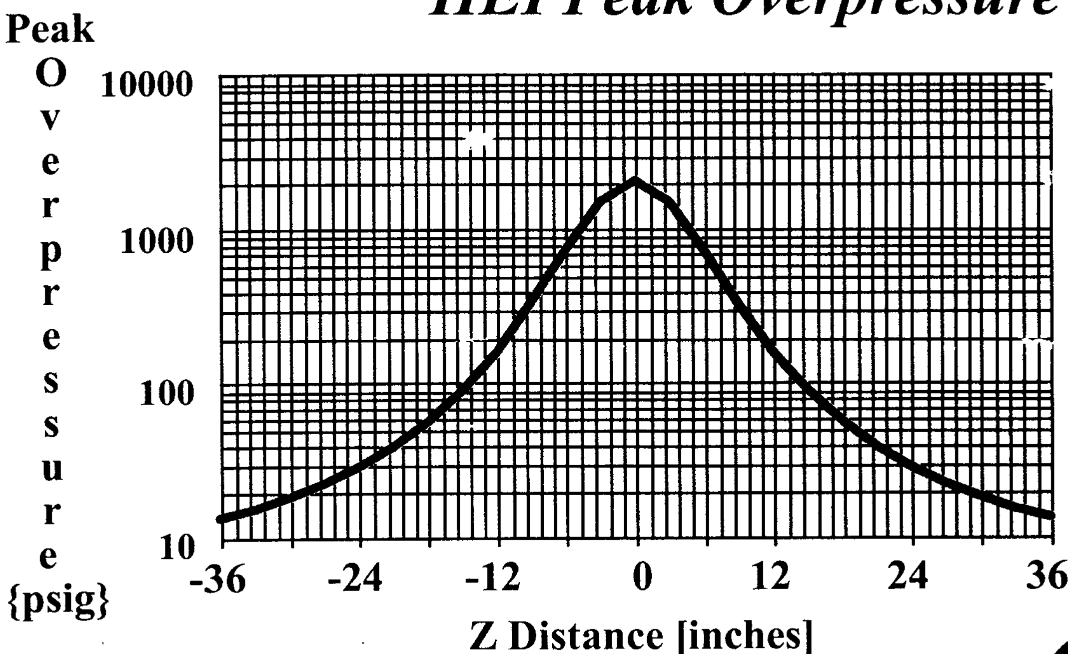
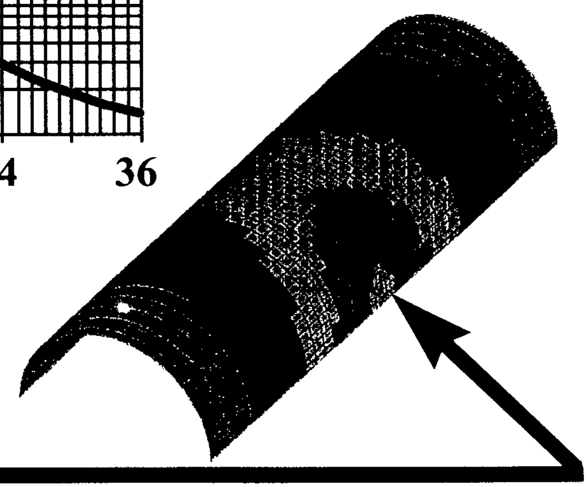
R&D Thermoplastic Tailboom Program

HEI Peak Overpressure



Peak overpressure along longitudinal lines detonating @ 4 to 6 in after penetration



Projectile Direction

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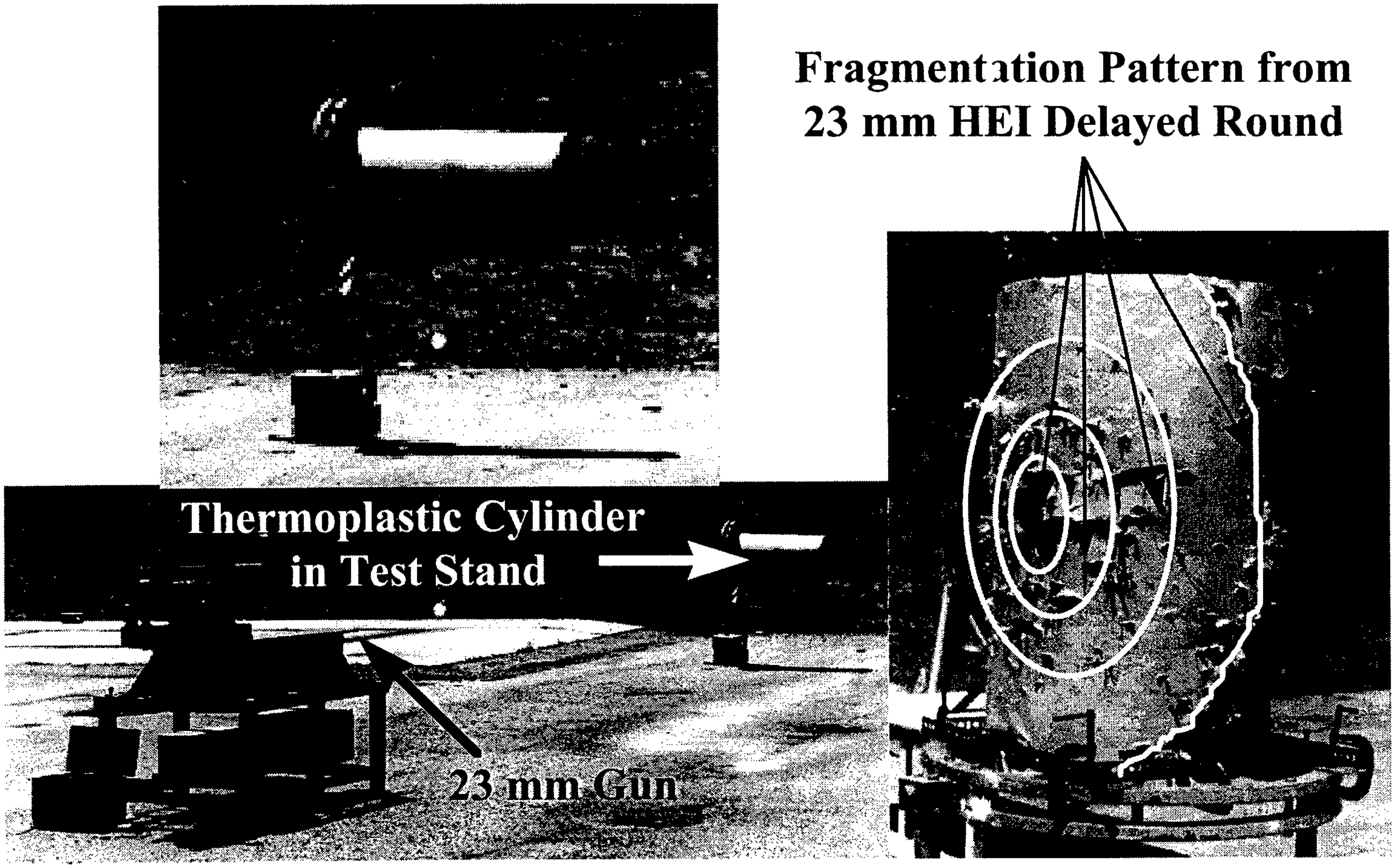
IR&D Thermoplastic Support

Fragmentation Pattern



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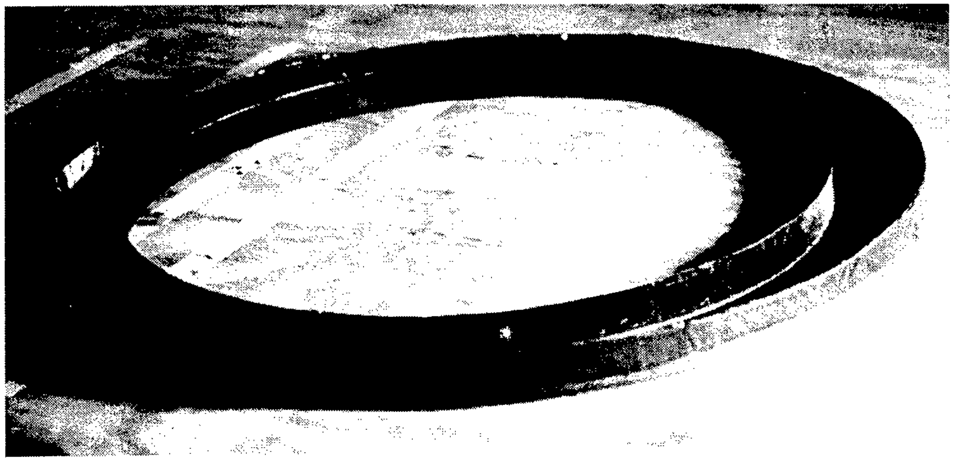
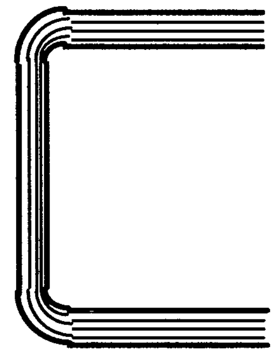
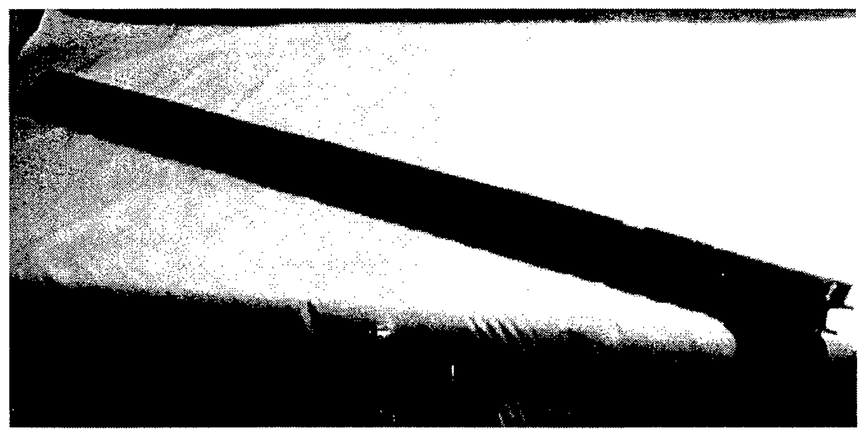
R&D Thermoplastic Tailboom Program

Fabrication - Frames & Longerons



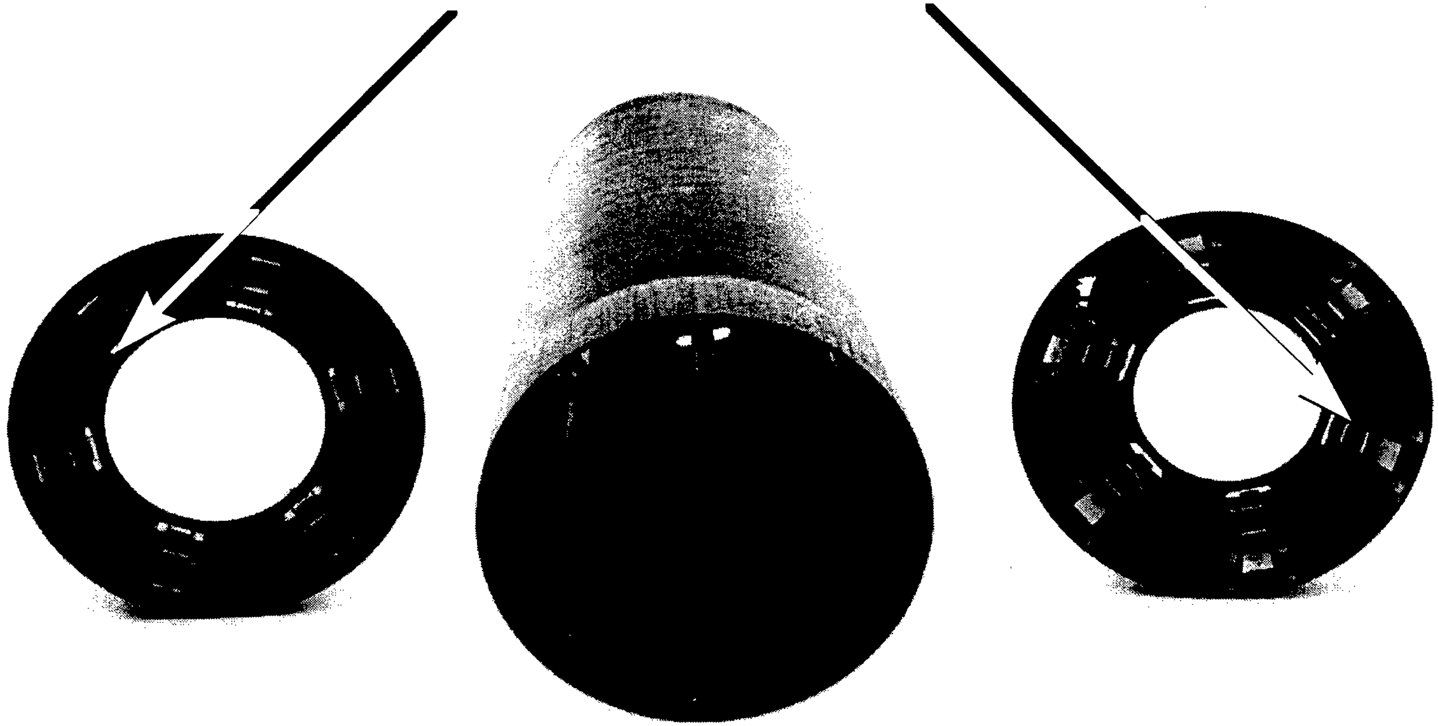
Frame





R&D Thermoplastic Tailboom Program

Doublers to strengthen frame cut-outs



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R&D Thermoplastic Tailboom Program

- **LONGERONS**
  - √ Single Tool - Two tools would reduce cost to 6 Mhs/Pound
  - √ High percentage of time in pressure vessel
  - √ 30% reduction with IR heaters

- **FRAMES**
  - √ Most Expensive Part to Make
    - Stamping channel preforms
    - Co-consolidation
  - √ C - Channel was fabricated in four 90° sections
    - Hand lay-up then cut to a circular arc
    - Polyimide sheets placed in center of laminate
  - √ Full C -Channel frame could be fabricated in one step

- **SKIN**
  - √ Increasing size of tape would speed up winding
    - Increase tape thickness {reduces # of plies}
    - Increase tape width {reduces # of strips per ply}

Fabrication Cost Summary

Component	Completed Part MH/Lb	Completed Part MH	Possible Reduction MH/Lb	Possible Reduction MH	% Reduction
Longeron	7.5	126.0	6.0	100.8	
Frame	25.0	132.5	12.0	63.6	
Skin	2.5	43.0	2.0	34.4	
Adjusted	7.8		5.1		34.6
Total		301.5		198.8	34.1

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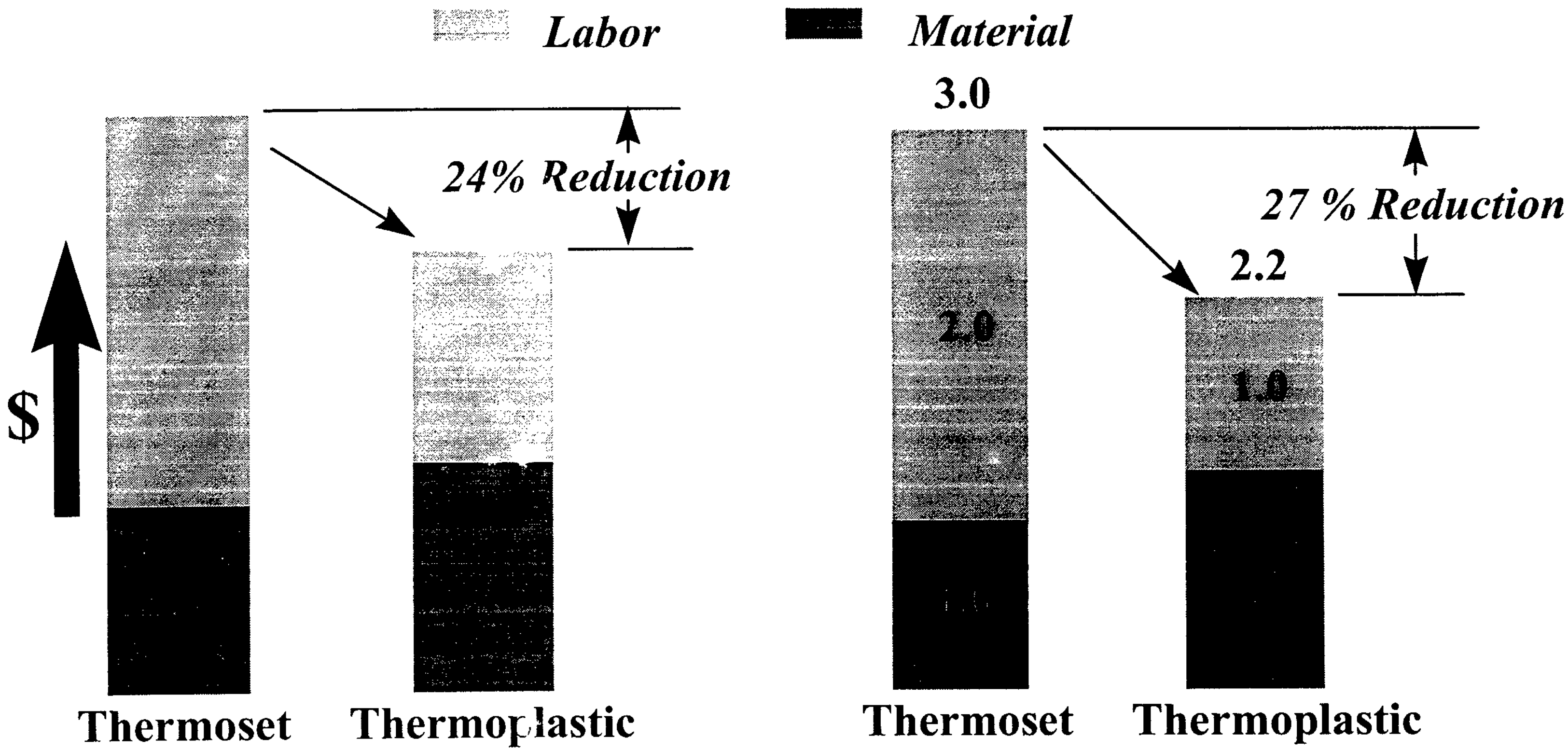
R&D Thermoplastic Tailboom Program

Thermoset vs Thermoplastic Panels



Source of Data: January 1995 Journal of Advanced Materials

Source of Data: Aviation Applied Technology Directorate {AATD}

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R&D Thermoplastic Tailboom Program

Test Matrix

Specimen	Baseline Stiffness	Ballistic	Ballistic Fatigue	Laser & Repair	Patch Fatigue	Ultimate
16 -Ply IM7/PEEK {Military Grade}	X	X	X			X
16 -Ply AS4/PPS { Commercial}	X	X	X			X
10 -Ply IM7/PEEK {Military Grade}	X	X	X			X
16 -Ply IM7/PEEK {Military Grade}	X			X	X	
10 -Ply IM7/PEEK {Military Grade}	X			X	X	

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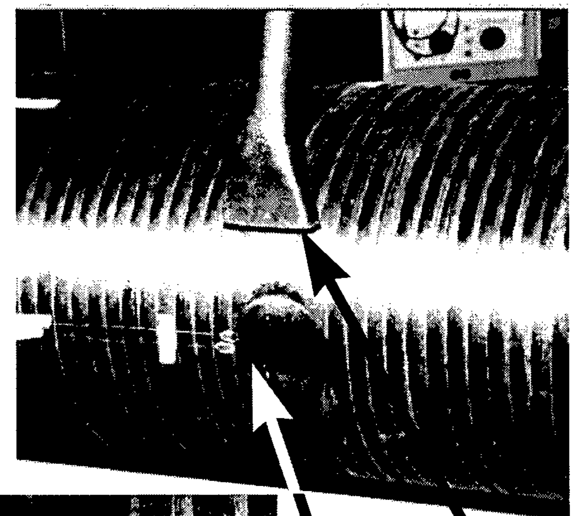
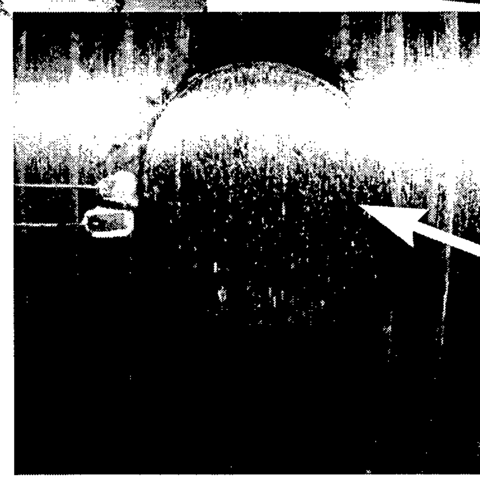
R&D Thermoplastic Tailboom Program

Hard Skin Tailboom under Load in WPAFB Laser Test Facility





Airflow Duct

Lased Area

NOTE:
- **Temperature on surface reached 1300°C{~2400°F}**
- **Damage - less than anticipated**
- **Power setting - significantly higher than typical threat levels**

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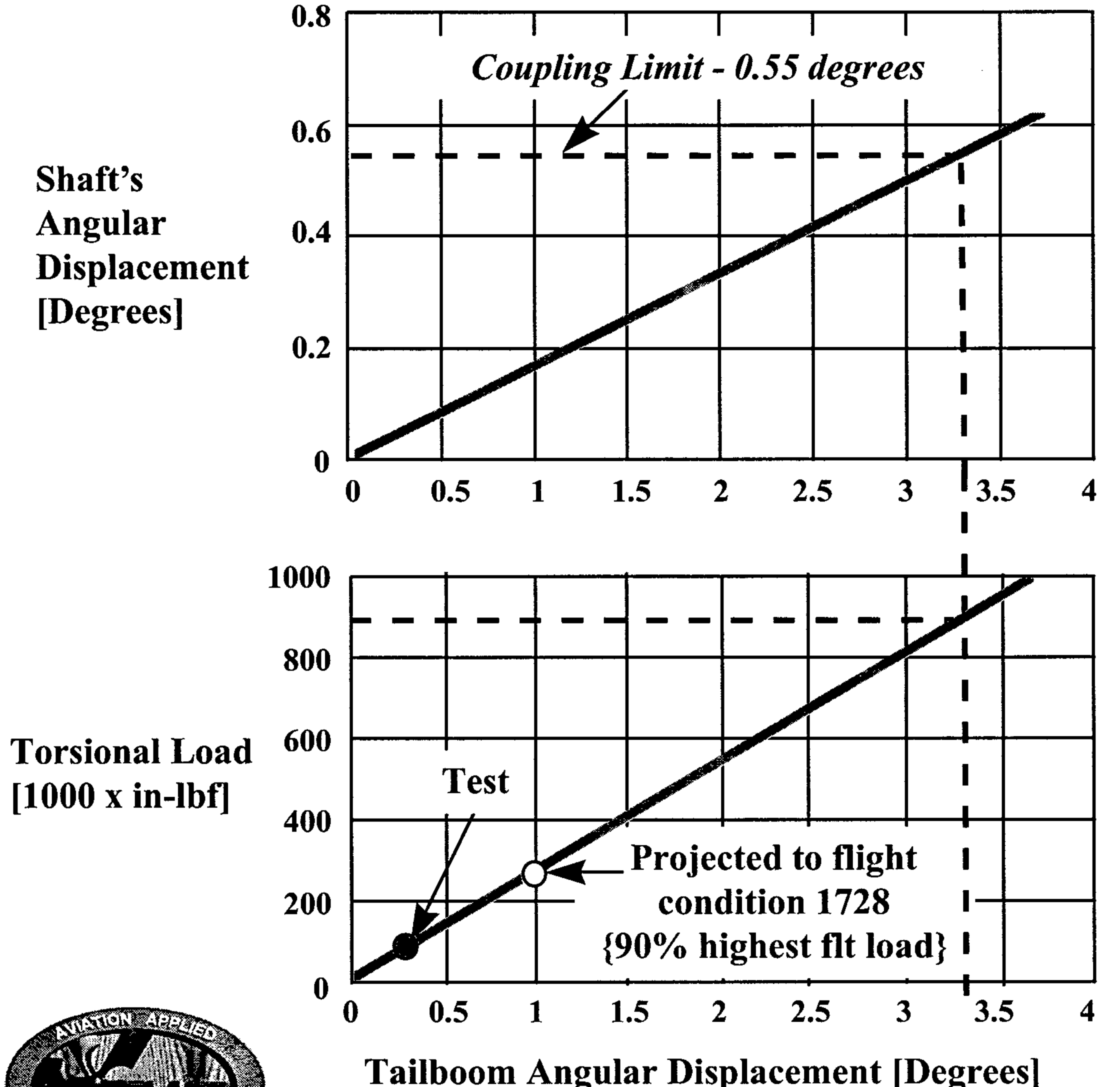
R&D Thermoplastic Tailboom Program



NOTES:

- Coupling misalignment limit of 0.55 degrees is produced by 3.3degrees of tailboom displacement

- Tailboom displacement requires 890,000 in-lbf torsional load

Conclusion:

Damaged tailboom maintains the tail rotor shaft's misalignment within allowable limits

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R&D Thermoplastic Tailboom Program

Conclusions

- 20% estimated weight savings over thermosets
- 25% estimated fabrication cost savings over thermosets
- No autoclave was required
- No fasteners were used between frames, longerons, & skins
- Limited delamination due to 23mm HEI damage
- Laser test level significantly higher than typical threat levels
- Field repair successfully demonstrated
- Met strength & stiffness requirements after 23mm HEI damage
- High temperature environment operation
  {IM7/PEEK, 250° F wet, 290° F dry}
- Excellent toughness
- Thermoplastics is NOT high risk technology any longer